

# CONCEPTUAL DESIGN AND COST INPUTS ASSOCIATED WITH CO-DISPOSAL OF THE SPENT FUEL AND LONG LIVED RADIOACTIVE WASTES IN THE DEEP GEOLOGIC DISPOSAL FACILITY

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## ABSTRACT

The paper aims to be an integrated approach for the containment and isolation of spent fuel and / or long lived radioactive wastes in a Deep Geologic Repository in Romania. Several scenarios could be defined for the management of spent fuel and long lived radioactive waste in Romania considering many specific constraints in Romania (political, geological, economic, demographic, etc.). This paper intends to be an upgrade of several Research, Development and Demonstration (RD&D) works performed by SITON specialists on this subject, taking into account also the conclusions of the Workshop “Cost estimation on spent nuclear fuel disposal in Romania” organized by IAEA in cooperation with ANDR at the beginning of this year in Romania. This paper is, also, addressed to decision makers with target on to adopt the best strategy for construction of Deep Geologic Repository in Romania

**Key words: deep geologic repository, cost estimate**

## Introduction

This paper aims to be an integrated approach for the containment and isolation of spent fuel and / or long lived radioactive wastes in a Deep Geologic Repository - DGR (DGMA, in Romanian) in Romania. All considerations made here are based on previous documentations developed by SITON within National Research and Development Program for Spent Fuel and Radioactive Waste Management but, also, on several updated information issued by Nuclear Waste Management Organization in Canada as part of the long term management for used nuclear fuel [1].

Several scenarios could be defined for the management of spent fuel and long lived radioactive waste in Romania. Because there are many specific constraints in Romania (political, geological, economic, demographic, etc.), SITON took into account the design experience from countries with old nuclear programs and for this reason it was considered the option of waste “co-disposal”. Conceptual design and cost inputs considered for the main development activities for this facility were discussed, considering

that in present there is no updated strategy on waste management, no design and no host rock formation for the DGMA in Romania.

There are many complex aspects related to cost estimates. For this reason, it could be expected that (based on real final waste inventories) further modifications of forecasted figures will occur. This is due to uncertainties for future evolution of the Romanian nuclear program (ambiguity regarding the commissioning date of Cernavodă NPP Unit 3 & 4, on extension of service life of the present operating units, on development of another type of reactor, etc.).

This paper intends to be an upgrade of several Research, Development and Demonstration (RD&D) works performed by SITON specialists on this subject, taking into account also the conclusions of the Workshop “Cost estimation on spent nuclear fuel disposal in Romania” organized by IAEA in cooperation with ANDR at the beginning of this year in Romania. The paper is, also, addressed to decision makers with target on to adopt the best strategy for construction of Deep Geologic Repository in Romania

### **Background information on previous works performed**

In 2006, SITON specialists initiated a research work in order to achieve a preliminary assessment of the costs associated with the development of a deep geologic repository for final disposal of high level wastes and spent nuclear fuel from Cernavodă NPP operation.

This paper is based on the previous mentioned work and has in intention a review of the above and, also, a tentative to re-introduce in discussion the upgrading of costs associated with final disposal of high level wastes and spent nuclear fuel in Romania.

It is worth to be mentioned that all works were and are performed in the condition in Romania there is in this moment no:

- Concept for deep geologic disposal of radioactive wastes;
- Selected host rock.

In 2006 the DGR development assumptions were as follows:

- DGR facility will dispose both spent fuel and long life wastes from 4 Cernavoda Units operation (30 years life) and decommissioning of them;
- The concept is generic and has not been based on conditions at any particular site. There is NO host rock established and NO proposed site. It was assumed a Generic Site;
- It is assumed that the repository will be located for both waste types at a depth between 500-1000 m;
- Prior to the receipt at DGR facility, spent fuel is stored in the existing Cernavoda Interim Dry Storage Facility for minimum 50 years.

A general layout was proposed, as shown in **Figure 1**. In **Figure 2** it is presented an earlier proposal of SITON (issued in 2006) for the time schedule for the development of the long lived radioactive waste and spent fuel repository, and, in table 1 the corresponding review of costs for several countries involved in research programs for deep geological disposal.

RAAN – SITON, in cooperation with other research institutes and regulatory bodies, has launched a new research initiative related to the safe final disposal of spent fuel and high-level waste. In 2008, SITON developed an R&D programme, coordinated by AN&DR, focusing on deep geological alternatives. This research was financed by the Ministry of Economy and Finances and carried out as part of a regional R&D programme. Several preliminary conclusions were growing regarding concepts to be applied for the development of HLW/SF repository in Romania, with respect to the host rock selection process:

- Romania is a small country with a high population density.
- Romania’s rich array of natural resources (oil & natural gas deposits, mineral ores, geothermal waters, forests etc.), could present difficulties when siting a geologic repository’
- Many apparently acceptable locations have had to be excluded from the selection process - even when they satisfied the IAEA selection criteria for host rock formation.

As a result of applying all known criteria, with the correspondise weight, according to MAA methodology, the following hierarchy arises presented in **Table 2**.

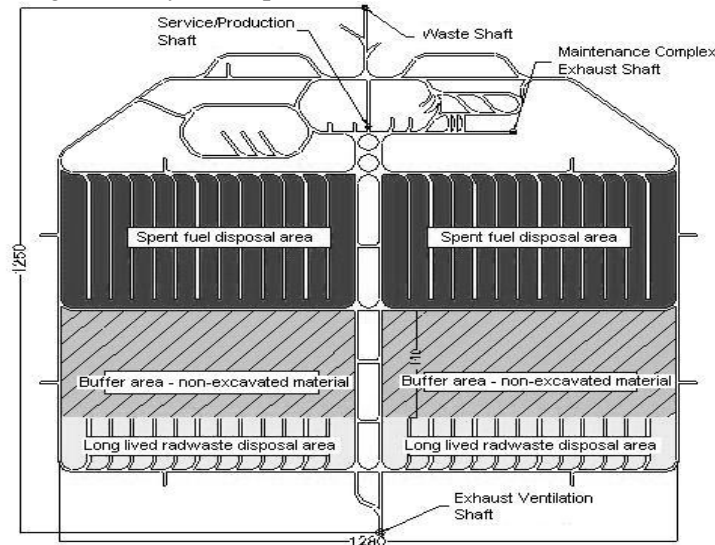


Figure 1 DGR General Layout as proposed by SITON in 2006 [1]

**Time schedule (years) – Long lived radioactive waste and spent fuel repository**

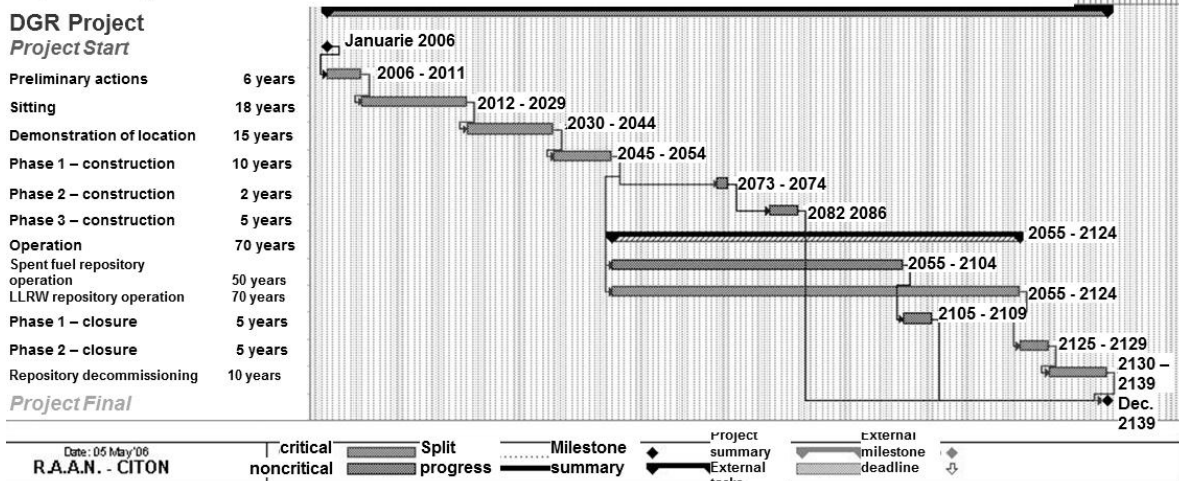


Figure 2 Tentative for a time schedule for the development of the long lived radioactive waste and spent fuel repository, SITON proposal in 2006 [1]

Table 1 Review of cost elements for disposal (million euro) for several countries [1]

Country (estimation year)	Spent fuel (TMG)	R&D	Sitting Cost	Construction Cost	Operation Cost	Closure Cost	TOTAL	Cost/ TMG million Euro/TMG
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Country (estimation year)	Spent fuel (TMG)	R&D	Sitting Cost	Construction Cost	Operation Cost	Closure Cost	TOTAL	Cost/ TMG million Euro/TMG
Belgium (2000)	4320	150	-	-	-	-	≤1700	≤0.39
Canada (1991)	90000	540	1738	1385	3297	1090	8050	0.090
Cech Republic (1999)	3724	181	28.4	260	797.2	10.3	1278	0.34
Finland* (2004)	5643	-		503*	1923	116	2542	0.45
Hungary (2000)	1300	25	152.3	580	323	121	1202	1.19
Japan (2001)	54000	909	1915	7953	5983	684	17445	0.32
Slovakia (2000)	2500	202	-	496	657	80	1435	0.58
Sweden (2001)	9000	-	-	2052		-	2910	0.32
UK (2005)	9000	-	1087	2275	1944	402	5708	0.63
Swiss (2001)	3000	-	558	767	419	279	2023	0.67
USA (2000)	70000	-	6528	16549	17224		40301	0.57

### New data for costs estimates of geological disposal for spent nuclear fuel and long-lived L&ILW in Romania

Considering the methodology adopted by RAAN-SITON in 2006 to assess geological disposal costs relying on cost data from similar geological repository projects in Sweden, Finland, Canada, etc. it is clear that it was an estimations with lot of uncertainties. Even in this situation, in the absence of an engineering work design for the Romanian DGR, the only existent method to assess costs is the use and proposal of figures based on data from similar foreign projects. This approach was adopted in 2006 and it is shown in **Table 3**.

The re-evaluation of disposal costs requires a significant effort considering that in this moment many constraints encountered in 2006 are still present. The importance of an accurate figure regarding the total costs associated with final geological disposal of radioactive waste resides in the correctness of the yearly fee to be paid in Romania for RW final disposal & decommissioning. These funds are extremely

important and will financial assist AN&DR in future in all activities related to the radioactive waste management.

**Table 2** *Classification of geological formations considering the IAEA criteria*

Classification of geological formations	Sites
Green schists	Casimcea
	Rahman
Granites	Vf Pietrii
	Bocşa-Ocna de Fier
Basalts	Bătuţa
	Pârneşti
Clay	Lower Sarmatian clays in the North Eastern extremity of the Moldavian Platform
	Pannonian clays from Oradea-Curtici region
Tuffs	Lunca Bradului
Salt	Dealul Dumbravei
	Brădeşti

This paper has no intention to issue costs estimates considering the preservation of many uncertainties related with deep geologic repository in Romania. The intention of the RW specialists in SITON and not only it is to stress on need to strengthen the research team capability, in the area related to cost estimation methodologies, and to improve the national capacity to safely manage radioactive waste.

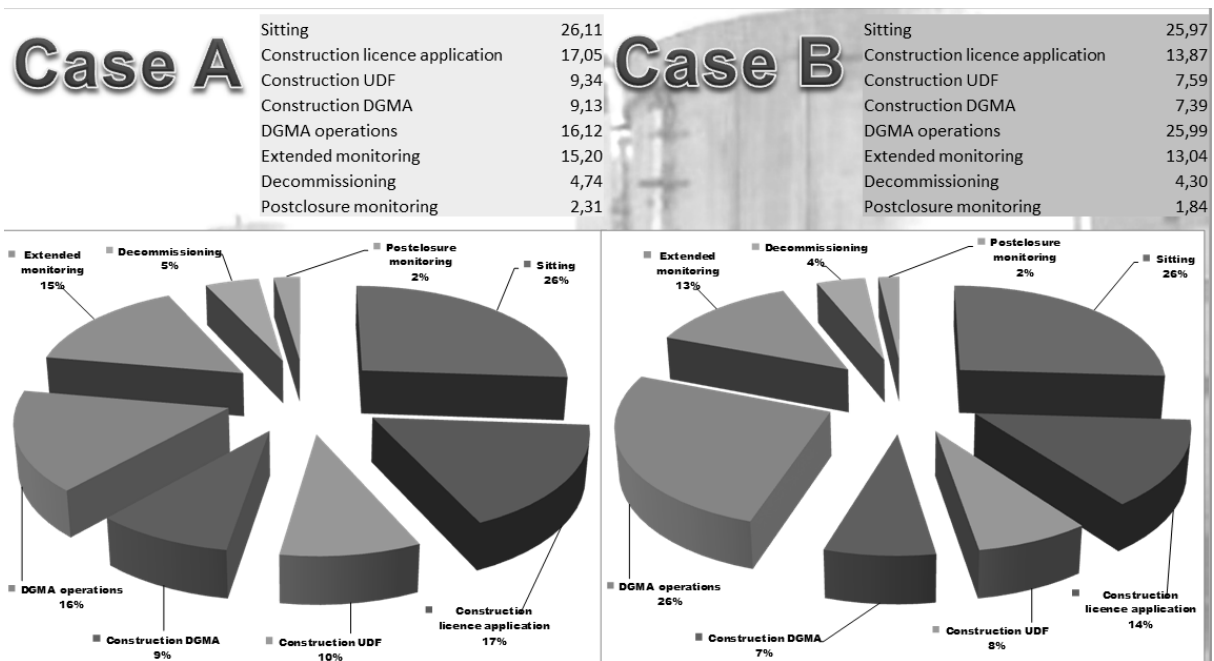
Several parameters can influence the R&D and siting costs:

- Nature and characteristics of the selected geological host formation;
- Number of sites to be investigated and extent of the site characterization programme;
- Type and extent of underground research facility, i.e. completely separated from the future geological repository or partially integrated into the future repository;
- Scope and extent of RD&D and site characterization activities to be carried out underground in the laboratory;
- Duration of the siting and R&D phase (the presently assumed 33 year-long could probably be shortened).

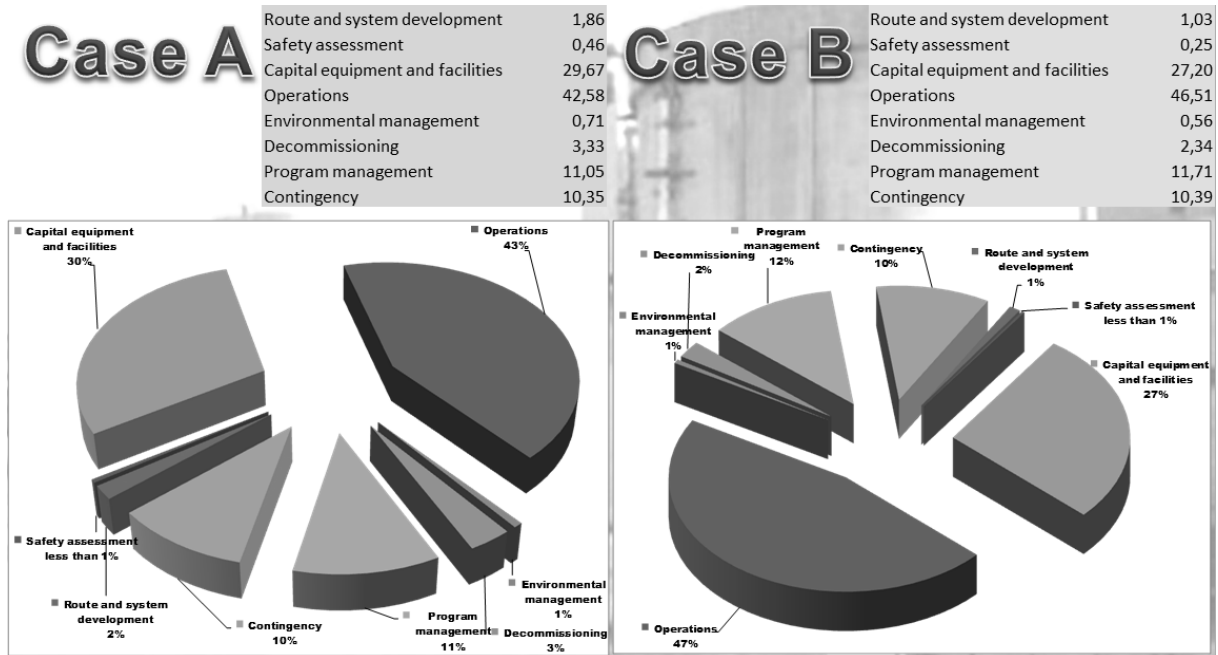
This aspects are schematically showed in figures 3 and 4 that resumes several costs estimates performed by NWMO for the Canadian DGR. Case A and Case B refers to two considered inventories for spent fuel (3,6 million bundles, and 7.2 million bundles, respectively).

**Table 3** Assessment of costs is the use and proposal of figures based on data from similar foreign projects [1]

Item no.	Activity	NIREX / crystalline (9.000 TMG) Spent fuel (Million euro)	CANADA/ crystalline (90.000 t) Spent fuel CANDU (Million euro)	Finland / crystalline 5.643 TMG) Spent fuel (Million euro)	NAGRA / sedimentary (3.000 TMG) (Million euro)	Romania (11.500 TMG) (Million euro)
1.	Sitting and characterization	1087	2278,0	-	558,0	1.000
2.	Construction	2275	1385	503	767	1025
3.	Operation	1944	3297	1923	419	550
4.	Sealing and closure	402	1090	116	279	300
<b>TOTAL</b>		5708	8050	2542	2023	2875
Total cost per TMG		0,63	0,90	0,45	0,67	0,25



**Figure 3** Costs estimates performed by NWMO for the Canadian DGR – disposal facility related costs [2]



**Figure 4** Costs estimates performed by NWMO for the Canadian DGR – transportation to the disposal facility related costs [2]

In order to optimize the extent of the Romanian RD&D programme on geological disposal to be performed in Romania some information can be considered from those countries with mature RD international programmes in this field.

The 2006 evaluation performed by SITON is rather in agreement with the breakdown of activities considered by the Canadians, with some amendments.

In this respect, construction costs estimated by RAAN-SITON spread over three time periods:

- Initial construction phase 2045 – 2054, i.e. 10 years construction of the main infrastructure, including
  - Total cost : € 750 million
- First extension 2073 – 2074, i.e. 2 years - cost : € 95 million
- Second extension 2082 – 2086, i.e. 5 years - Cost : € 180 million

Canadian and Romanian construction cost estimates can usefully be compared at least for the fixed cost components mentioned above – **Table 4**.

**Table 4** Canadian and Romanian construction cost estimates [2]

Construction costs in million €	Canadian DGR*	Romanian repository
Surface buildings & facilities	758	200
Surface & underground infrastructure	116	175
Shafts & ramps		
Total construction costs, excluding disposal areas	<b>874</b>	<b>375</b>

The estimated operating cost for spent fuel was derived from the Canadian disposal cost on a pro-rata basis (ratio 6:1 based on quantity of canisters to be disposed of). Also, there is a lack of information referring to costs associated with transportation in the SITON evaluation because it is not clear in this moment the location of the disposal facility versus the Cernavodă NPP. Additionally, no provision is made for site environmental monitoring costs after closure and decommissioning of the geological

repository. The reason may be due to the lack of regulatory requirements for geological disposal of radioactive waste and spent nuclear fuel in Romania.

## Conclusion

Estimates presented by SITON in the past on costs, as well as their justification, were based strictly on information from the specialised literature. There are complex aspects related with costs evaluations, an aspect that is revealed also by the existence of dissimilar approaches of different national programmes for final disposal of RW. Moreover, the inventories of spent nuclear fuel considered for the evaluations will be further updated, including in case of Romania, due to the probable extension of the service life of the NPP up to 60 years.

For this reason, the risk for an underestimated value is considered by all analysed national RW final disposal programmes and differs greatly from one country to another. The correction factor is estimated to range between 20 % and 100 %.

For the study realised by the Romanian researchers in 2006 it forecasted an average risk coefficient on of the investment total costs of more than 50 %. SITON urges for preliminary actions for final disposal of spent fuel and long lived radioactive wastes.

Another important component of the costs is related to the development of an underground research facility for scientific assessments and of the technologies and materials considered for DGMA development in order to guarantee the constructional and operational safety of the final repository.

The update of geological disposal costs implies definition of hypothesis, constraints, requirements and scenarios for spent fuel and radioactive waste management deep geological disposal because in this moment development, operating and monitoring costs for the Romanian geological repository is significantly underestimated. This due to uncertainties for future evolution of the Romanian nuclear program (ambiguity regarding the commissioning date of Cernavodă NPP Unit 3 & 4, on extension of service life of the present operating units, on development and implementation of another type of reactor, etc.).

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